The problem of identifying decametric sources

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Abstract

We describe a method to construct continuum spectra for radio sources on the basis of entries from various source catalogues in comparatively large error boxes around a given sky position. Sources from the UTR-2 catalogue (Braude et al. 1978–1994), observed at decametric wavelengths (10–25 MHz) with an antenna beam of about 40′, were cross-identified with entries from other radio catalogues at higher frequencies. Using the CATS database we extracted all sources within 40′ around UTR positions to find candidate identifications. A spectrum for each source was fitted with a set of curves using a least-squares method to find the best fit. We preferentially selected radio counterparts whose radio spectrum extrapolated to low frequencies matched the UTR decametric flux densities, and whose coordinates were close to the gravity center of UTR positions. Among all the 1822 sources in the UTR catalogue we found about 350 sources to be blends of two or more sources. As the most probable true coordinates of the radio counterparts we used positions from the NVSS, TXS, GB6, or PMN catalogues. Using low-frequency sources (26, 38, 85 MHz) from CATS we checked the reliability of some of our IDs. We show examples of the above methods, including raw and "cleaned" spectra.

1 Introduction

The catalog of 1822 radio sources obtained with the UTR telescope near Kharkov (Braude et al. 1978–1994, `http://www.ira.kharkov.ua/UTR2/`) covers about 30% of the sky at six frequencies from 10 to 25 MHz, and is currently the lowest-frequency catalog of its size. It provides an ideal basis to study the little known optical identification content of sources selected at decametric frequencies. The optical identification rate in the original version of the UTR-2 catalog (UTR in what follows) is only 19%. Our goal is to identify all UTR sources with known radio sources. This cross-identification yields both the radio continuum spectrum and accurate coordinates for the radio counterparts, thus allowing to search for optical counterparts on the Digitzed Sky Surveys. The radio spectral characteristics may also be used to select certain samples, e.g. steep radio spectra and the lack of an optical identification tend to point to high-redshift radio galaxies.

The very large uncertainties of the UTR source positions ($\sim$0.7°) forced us to use an interactive process to derive radio source spectra. In this process we use the radio sources known from low- and intermediate-frequency catalogues as the most likely candidates, which help us to discard the multitude of weaker sources in the UTR error box provided e.g. by the recent and sensitive NVSS and FIRST source catalogues. All catalog entries are extracted from the catalog collection combined in the CATS database (Verkhodanov et al., 1997).

Characteristics of the main catalogs, used in identification, are given in Table 2.

Name	Freq.	HPBW(')	S_{lim}(mJy)	Reference
6C	151	4.2	∼200	1993MNRAS.263...25Hales+
7C	151	1.2	80	1990MNRAS.246..110McGilchrist+
MIYUN	232	3.8	∼100	1997A&AS..121...59Zhang+
TXS	365	∼0.1	∼200	1996AJ....111.1945Douglas+
B3	408	3×5	100	1985A&AS...59..255Ficarra+
WB92	1400	10×11	150	1992ApJS...79..331White+
87GB	4850	3.7	25	1991ApJS...75.1011Gregory+
GB6	4850	3.7	15	1996ApJS..103..427Gregory+
PMN	4850	4.2	30	1996ApJS..103..145Wright+
MSL	misc.	misc.	misc.	1970ApJS...20....1Dixon

3 Construction of Radio Continuum Spectra

To prepare radio continuum spectra for decametric sources of the UTR catalog (Braude et al., 1978–1994), detected at 10, 12.6, 14.7, 16.7, 20, and 25 MHz, we first need to identify the sources with other known radio sources within their large error boxes (we used a box of $40' \times 40'$) drawn from the CATS database. CATS provides a graphical interface which displays a “radio spectrum” for all sources found in the error box at various frequencies. By human interaction the most deviant flux measurements in the spectrum can be recognized as an inappropriate counterpart, and is discarded from the spectrum. This “cleaning” is achieved with the program *spg* (Verkhodanov, 1997).

1. From the main radio catalogs of the CATS database (Verkhodanov et al., 1997), we extract all entries in the search box of $40' \times 40'$, except for the recent and very sensitive NVSS and FIRST catalogs.

2. All objects with flux measurements at several frequencies, are separated in the search box of $40' \times 40'$.

3. The spectrum of each object, excluding the UTR data points, is fitted with one of several curves and extrapolated to the UTR frequencies.

4. Inside the search box we select counterparts by the following rules:
   (a) the decametric flux densities, as extrapolated from the fitted spectra, should be close to the observed UTR fluxes;
   (b) positions of the radio counterparts should be close to the mean position as listed in the UTR catalog.

   The resulting number of candidate identifications per UTR source ranges from 1 to 4 (see also Fig. 1). In the case of more than one counterpart, we consider that all counterparts satisfying the described criteria contribute to the UTR source flux, i.e. the UTR detection is a result of blending of one or more independent sources.

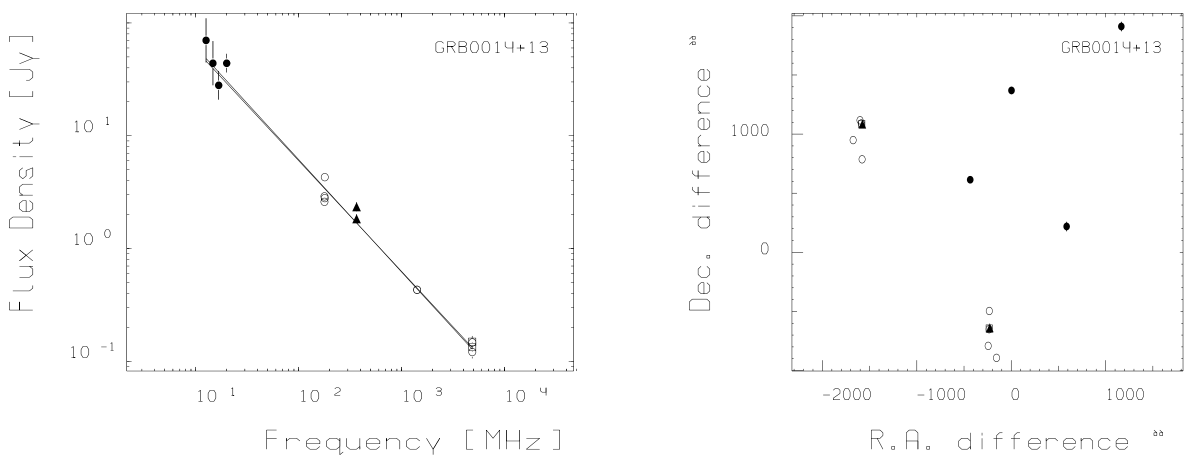

Figure 1: Left panel: spectra of two sources contributing to one UTR object. Their contribution in the radio spectrum is practically indistinguishable. The right panel shows the relative positions of all entries contributing to the spectrum. Two clusters (corresponding to 2 blending sources) are visible at the lower and left edge of the chart. The filled dots correspond to UTR fluxes and positions, respectively. The data have already been cleaned from other irrelevant sources in the area. The filled sources are UTR points.

lowing catalogs (in order of decreasing priority): TXS (365 MHz), GB6 (4850 MHz), 87GB (4850 MHz), PMN (4850 MHz). Data from at least one of these catalogs are included in the information on radio counterparts inside the search box.

6. If the identification area is poor of objects (e.g. at low declination, covered by only few radio surveys), and there are no sources detected simultaneously at several frequencies (i.e. no spectral fit was possible), then all objects within the box were retained for further study.

7. The best radio coordinates were then used for identification with NVSS or FIRST sources. Using flux densities from NVSS or FIRST usually improved the smoothness of the radio spectra.

8. Only if an NVSS identification was found, the "best radio positions" of item 5 were overwritten with the NVSS position.

9. The "best radio positions" are used for identification of UTR objects with optical object catalogues (e.g. from the APM scans of POSS or ESO/SERC surveys) or catalogs in other wavelength ranges.

One of problems of identification inside a wide antenna beam is source confusion when one real source has more than one sidelobe. We have considered such sources and mark them as 'conf' in Table 1. An example of one such source is shown in Fig. 2.

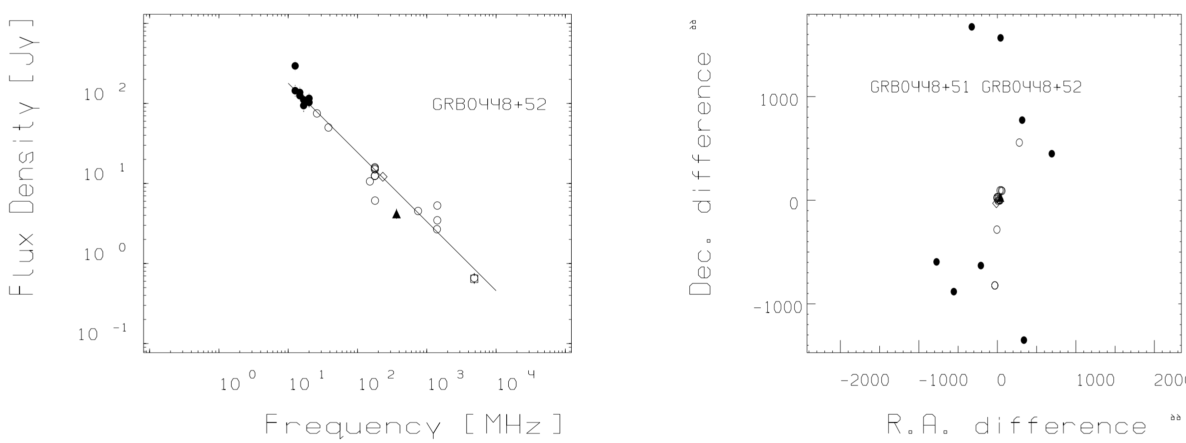

Figure 2: Example of a real source (4C 52) which has been observed as two independent UTR sources in adjacent observational strips. The left panel shows a spectrum, and the right panel shows the position of a confused source.

To check the reliability of the derived spectra we used the low frequency catalogs 6C, 7C (151 MHz), 3C,4C (178 MHz), and other catalogs included in Dixon's Master List, like CL (Viner & Erickson 1975, 26 MHz), WKB (Williams, Kenderdine & Baldwin 1966, 38 MHz), MSH (Mills, Slee & Hill 1958–61, 85 MHz). Although these do not cover the entire UTR survey area, they confirm the high reliability of our methods in the region where these surveys overlap.

The resulting catalog of 2314 radio counterparts, including all blends, is given in Table 1. In the columns of this table we give the original (B1950-based) UTR source name, the R.A. and DEC (J2000.0) of the best radio position, galactic longitude and latitude, best-fitting radio spectral parameters, presence of an optical, infrared or X-ray counterpart, and other names.

Only for three sources we were unable to find identifications among the catalogs described above: GR0801−11, GR0930−00, GR1040−02.

There are not enough data to be sure of the identifications of the sources GR0520−08q, GR0537−00, GR0629+02, and GR2345+03.

We worked with both existing versions of the UTR catalog: the printed version (Braude et al., 1978, 1979, 1981, 1985, 1994) and the more recent electronic one (`http://www.ira.kharkov.ua/UTR2/`). We included UTR sources of all reliability levels (A,B,C) as given in the UTR catalog.

In Table 1 we kept the names from the printed catalog version for the following sources (new names from the electronic version are given in brackets):
GR0224+03 (GR0227+03), GR0307+17 (GR0307+16), GR0411+14 (GR0411+13),
GR0919+55 (GR0918+55), GR0929+07 (GR0930+07), GR1039+03 (GR1039+02),
GR1142+00 (GR1142−00), GR1538+01 (GR1539+01), GR1547+03 (GR1548+03).

Table 1 also includes the following sources, which are present in the printed version, but are absent in electronic one:
GR1915+56, GR2355+19, GR2355−02, GR2358+08.

5 Conclusion

This method including simultaneous account of spectra behavior and radio points concentration on the coordinates plain is a good solution for the problem of the identification radio sources observed with a large antenna beam.

Different subsamples of sources identified with the above methods are being studied by the authors.

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